# Biological Control of Spotted and Diffuse Knapweeds

Animal and Plant Health Inspection Service

Program Aid Number 1529

Cover: Adult root-boring weevil *Cyphocleonus achates*, originally from Greece, rests on a spotted knapweed flower head. Female adult weevils produce up to 100 eggs. The larvae feed in the root crown and below, causing a gall-like formation in the damaged area, reducing plant vigor, and making the plant more susceptible to disease.

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## The Problem

Spotted and diffuse knapweeds *(Centaurea maculosa* Lam. and *C. diffusa* Lam.) have infested millions of acres of rangeland in the United States. These invasive, exotic perennial weeds have reduced the carrying capacity of native rangelands by up to 90 percent. The weeds have very low palatability to both livestock and wildlife and have severely diminished the quality of wildlife habitat and the returns from livestock production. In Montana alone, a 1984 report estimated the value of annual forage losses caused by knapweeds to be $4.5 million (Bucher 1984).

**Figure 1**—Spotted knapweed may be attractive to the uninitiated but is a menace to livestock range and wildlife habitat.

Herbicide control of these weeds is fairly effective but can be cost prohibitive for several reasons. First, the weeds' numerous seeds have a unique ability to stay dormant in the soil for 8 to 10 years. Therefore, chemicals must be used in successive years to exhaust the "seed bank" in the soil. Second, because the weeds now occupy a vast expanse of dry mountainous rangeland of limited value, chemical control may not be economically feasible for most landowners. Knapweeds' growth in rough terrain further complicates chemical control.

To reduce these problems, the U.S. Department of Agriculture (USDA) is conducting a major biological control program that involves importing, propagating, and distributing the weeds' natural enemies. Biological control specialists in USDA's Animal and Plant Health Inspection Service (APHIS) are concentrating on insects that have evolved to feed only on spotted and diffuse knapweeds. Collectively, the feeding insects inhibit the weeds' growth and reproduction, reducing the plants' ability to compete with desirable native range plants.

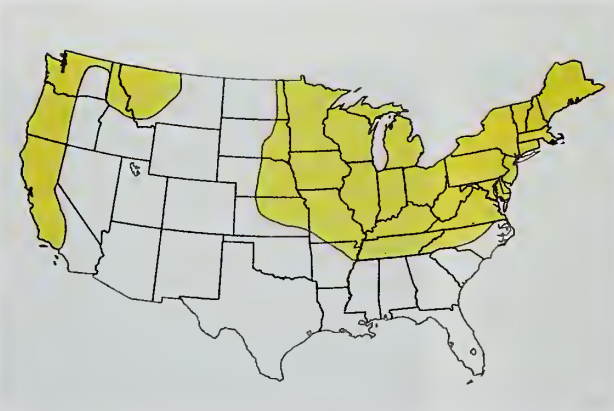

**Figure 2**—Spotted knapweed was first introduced from Eurasia in contaminated alfalfa and clover seed around 1893. Although scattered populations are found in at least 34 States, spotted knapweed infests in excess of 7.25 million acres in just 8 States and the Canadian Provinces of British Columbia and Alberta.

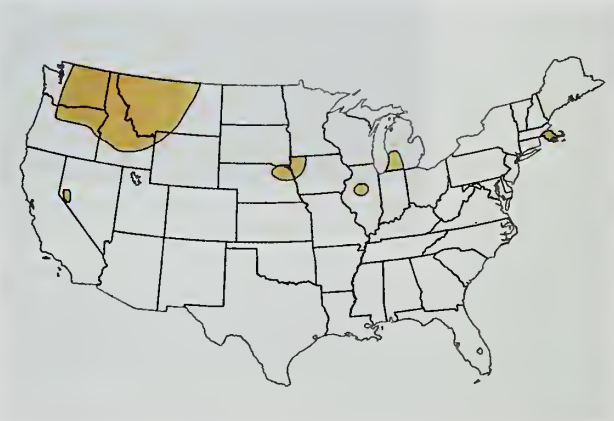

**Figure 3**—Diffuse knapweed, first reported in Washington in 1907, currently covers more than 3.21 million acres in 10 States and the southern part of British Columbia.

**Figure 4**—An old sewer line presents a perfect opportunity for spotted knapweed to establish itself. Spotted and diffuse knapweeds thrive in dry, sandy soils in old fields or disturbed sites, such as roadsides, gravel pits, or abandoned railway beds.

**Figure 6**—Stems of spotted knapweed terminate in a solitary pink or purple flower.

**Figure 7**—The basal leaves of the knapweed rosette grow up to 6 inches long and divide into leaflets along a common axis. The well-developed taproot system enables the plant to survive in dry areas.

**Figure 5**—These mature spotted knapweed heads have already distributed most of their seeds.

Although selective overgrazing of desirable native vegetation by herbivores enhances the knapweeds' ability to invade rangeland, the weeds' success is primarily the result of their prolific seed production and ability to distribute the seeds. Each flower produces 12–35 seeds, resulting in 400–25,000 seeds per plant, depending upon the soil moisture available to the plant. When the seeds ripen in early fall, the stems become brittle and the seedheads break off easily. Automobiles driven through such weed patches can transport the noxious weed seeds for many miles into previously uninfested areas. In diffuse knapweed's case, the plants may break off at the base and blow in the wind for a short distance, shaking out their seeds as they tumble along.

**Figure 8**—Plants of spotted knapweed have one or more stems that branch 1–3 feet tall.

**Figure 9**—The seed, tipped with a tuft of bristles, measures about 1/8 inch long.

**Figure 10**—Plants of diffuse knapweed, more branched than those of spotted knapweed, grow 1–2 feet tall. Compared to spotted knapweed, the leaves of diffuse knapweed are small, and the numerous flower heads are narrow with spiny bracts.

**Figure 11**—The flower of the diffuse knapweed plant is generally white but can be lavender or purple.

## Biological Control

In Europe and Asia, where spotted and diffuse knapweeds originated, sufficient natural enemies have developed over time to keep the knapweeds in balance with other plants native to those areas. Where insects and disease have stressed the knapweeds, the weeds are nothing more than wild flowers and exert no detrimental effects. However, because the weeds invaded North America without their natural enemies, they have reproduced unchecked here for more than 100 years.

USDA, APHIS—in cooperation with scientists in the USDA's Agricultural Research Service (ARS), Agricultural Experiment Stations (AES), and International Institute of Biological Control (IIBC)—has imported, propagated, and redistributed hundreds of thousands of biological control agents. Scientists employed by these agencies scour the European landscape for new species of beneficial insects. This extensive program relies upon cooperation from many Federal and State agencies, along with private landowners.

Currently, there are 12 beneficial insect species from Europe cleared by USDA for release in the United States. Most of these biological control agents attack

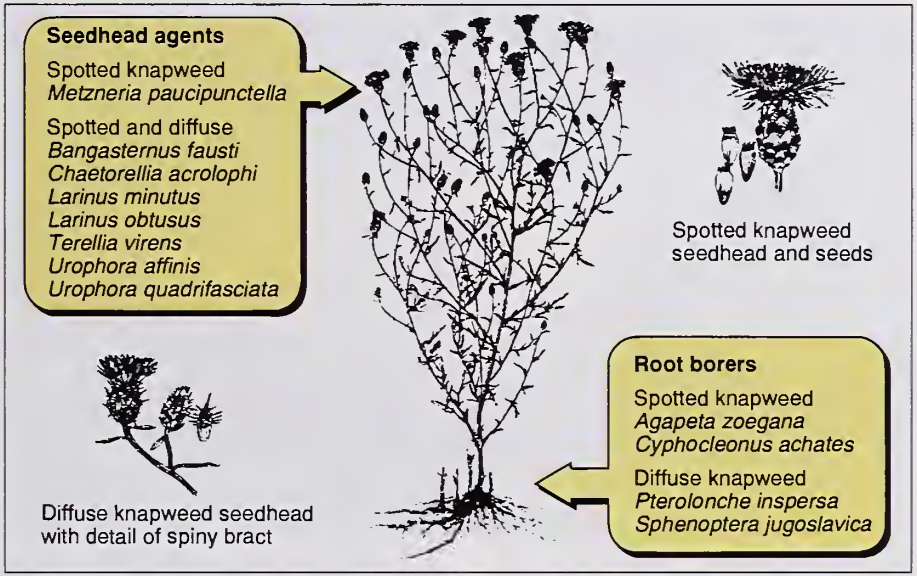


**Figure 12**—Location of biocontrol agent-induced damage on spotted and diffuse knapweed plants.

both species of knapweed, but a few are specific to just diffuse knapweed. The insects work together by feeding on the seeds or in the roots of the weeds. Each attack reduces the knapweeds' defenses by inhibiting seed production, either from direct destruction of seeds or by stunting overall growth and strength of the plant. In some cases, when the insect larvae burrow into the root, they allow naturally occurring soil components such as fungi and bacteria to enter the plant's system, further weakening the plant.

Eventually, scientists hope to propagate and redistribute sufficient insect populations to hold spotted and diffuse knapweeds to tolerable levels similar to their population in Europe.

**Figure 13**—*Agapeta zoegana,* a bright yellow moth, originates from the Mediterranean region of Europe.

**Figure 14**—*Agapeta zoegana* larvae possess the ability to move from one root to another upon depleting the food supply. Several larvae can occupy large roots.

**Root-Boring Insects**

Larvae of these insects mine the root of the plant, reducing storage capacity and increasing susceptibility to infection from fungi or bacteria. Plants attacked before they reach the critical size for flowering experience delayed bolting for 1 or more years, reducing flowering and production. Continued feeding by root-mining insects on weakened plants kills the weeds. Larvae of *Cyphocleonus achates* (cover photo) feed in the root crown and below, causing a gall-like formation in the damaged area.

*Pterolonche inspersa* (fig. 15), a brown moth from the northeastern Mediterranean region, and *Sphenoptera jugoslavica* (fig. 16), a European buprestid beetle, are both specific to diffuse knapweed. Their larvae mine the root of diffuse knapweed, reducing plant vitality and providing a port of entry for fungal infection.

**Figure 15**—*Pterolonche inspersa* adult moth.

**Figure 16**—*Sphenoptera jugoslavica* adult beetle.

**Figure 17**—*Sphenoptera jugoslavica* larva mining the taproot of diffuse knapweed.

**Seedhead Insects**

Larvae of these species can consume the entire contents of immature knapweed seedheads, including the seeds, florets, and portions of the receptacle. Most of the larvae of these species also cause gall-like structures in the seedhead. These galls are formed by the plant in response to the larval feeding and further deplete the plant's resources.

**Figure 18**—*Urophora affinis* adult fly. *U. affinis* and *U. quadrifasciata* are the most widely distributed of all the knapweed biocontrol agents.

**Figure 19**—Two *U. affinis* galls flank an exposed larva. The larvae of *U. affinis* and *U. quadrifasciata* inhibit seed production. In the process, they form a gall inside the seedhead, which depletes the plant's energy resources.

**Figure 21**—*Chaetorellia acrolophi,* from western Switzerland, can lay up to 12 eggs per day. This seedhead fly's larvae burrow into the center of the bud, eat their way through a floret down into the seed, and continue to another floret, usually destroying the entire contents of the seedhead.

**Figure 20**—*Terellia virens,* originating from the Mediterranean region, joins *Chaetorellia acrolophi* as APHIS' two newest weapons against knapweeds. Originally introduced in 1993, *T. virens'* larvae also attack the young seeds, burrowing inside and consuming the germ. In addition, the adult flies feed on the knapweed flowers.

**Figure 22**—*Bangasternus fausti* adult weevil.

*Bangasternus fausti, Larinus obtusus,* and *L. minutus* (figs. 22–24) are three species of seedhead weevils from central Europe and the Mediterranean. The adults of these weevils feed on the leaves, stems, and florets but prefer flower heads when available.

The larvae of all three insects eat the pappus hairs and the entire contents of individual seeds and then prepare for pupation by forming a cell of pappus hairs, seeds, and secretions in the seedhead.

**Figure 23**—*Larinus obtusus* adult weevil.

**Figure 24**—*Larinus minutus* adult weevil.

**Figure 25**—The *Larinus minutus* development chamber occupies most of the seedhead. Note the nonviable seed, remnants of larval feeding, "glued" to the sides.

**Figure 26—***Metzneria paucipunctella* adult moth.

The larvae of *Metzneria paucipunctella* (fig. 27), a small brown moth originating in Europe, feed on different areas of the spotted knapweed seedhead as they mature. Larvae first consume the florets, move on to the young seed and the receptacle, and finally consume the mature seed.

**Figure 27—***Metzneria paucipunctella* larva inside a spotted knapweed seedhead.

## Establishing Exotic Insects

Scientists evaluated the 12 potential biological control insects in laboratories and experimental plots in Europe and examined them in quarantine facilities in the United States. The entomologists made certain that insects intended for release were healthy, ensuring a successful establishment in North America, free of diseases and parasites.

Furthermore, they made sure that the new insects would be safe for release in the United States. Stringent import regulations prevent the introduction of foreign organisms that can damage desirable plants.

The scientists checked whether the insects would attack crop and pasture plants, including alfalfa and safflower. They also studied the insects' behavior toward North American wild plants closely related to spotted and diffuse knapweeds, such as common yarrow and common sunflower. The 12 selected biological control agents have all passed rigorous testing, and all are extremely particular about their diet.

After each agent was tested and approved for release in the United States, APHIS faced the challenge of securing a sufficient number of each species to release on the range. To encourage rapid population development, specialists developed methods to mass-produce some species using insectaries where specially designed cages are placed over plots of knapweed. The cages protect and contain the insects, enabling them to grow and multiply with minimal stress. Scientists use an intensive garden setting to raise other insects and carefully nurture the plants to foster maximum agent development. After sufficient populations of the insects develop in the garden setting, specialists collect and redistribute some of them to new insectary sites managed by county, State, or Federal cooperators. In this way, populations of insects are spread across the areas of the United States already infested with spotted and diffuse knapweed.

**Figure 28**—Nursery knapweed plants in the garden insectary are trimmed several times each summer to enhance root-boring insect production.

**Figure 29**—Scientists use a variety of methods to collect the insects for redistribution, ranging from small hand-held vacuums that suck the insects off the plants to old-fashioned hands-and-knees searching.

## What You Can Do

Ranchers need to be patient in waiting for the benefits from introduced enemies of spotted and diffuse knapweed. Because biological control is a gradual process, and because of the knapweed seed's ability to lie dormant in the soil for many years, it will take time to see results. Ranchers can help the process by restricting their use of herbicides and insecticides at or near insect release sites, thus enabling beneficial insects to multiply without harm from agricultural chemicals. Still, it can take many years to build up adequate numbers of a weed's natural enemies at any specific location. When the insects increase in number and knapweed becomes less abundant, the natural enemies search for other stands of the weed to attack. This natural process will continue for as long as knapweed is present.

Ranchers and outdoor enthusiasts can help by being conscientious and careful not to spread knapweed into new areas. Repeatedly, people unaware they were doing any harm have spread spotted and diffuse knapweed. The seed travels along unobtrusively on vehicles driven off maintained roads. Bumpers, doors, and undercarriages should always be checked before moving a vehicle to make certain the weeds are cleared away. Do not drive off-road vehicles, including pickups, four-wheelers, motorcycles, bicycles, and snowmobiles, through knapweed infestations.

Through conscientious monitoring of land-use habits, landowners and recreationists can help control the spread of these noxious weeds.

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